Alpha, Beta, and Gamma Decay

1) Determine whether these decay processes are possible.
   a) $^{212}_{84}Po \rightarrow ^{210}_{86}Rn + ^{4}_{2}\alpha$ (No)

Charge: 84 ≠ 86 + 2
Atomic Mass number: 212 ≠ 210 + 4
This equation violates the laws of conservation of charge and of atomic mass number. Therefore, this decay process is impossible.

   b) $^{233}_{91}Pa \rightarrow ^{233}_{92}U + ^{0}_{-1}\beta$ (Yes)

Charge: 91 = 92 – 1
Atomic mass number: 233 = 233
This equation is correct—both mass number and charge are conserved. Therefore, this decay process is possible.

   c) $^{14}_{6}C \rightarrow ^{14}_{7}N + ^{1}_{1}H$ (No)

Charge: 6 ≠ 7 + 1
Atomic mass number: 14 ≠ 14 + 1
This equation violates the laws of conservation of charge and of atomic mass number. Therefore, this decay process is impossible.

2) Write the α-decay process for these elements, and name the parent and daughter elements.

All alpha decay processes fit the pattern $^{A}_{Z}\mathrm{X} \rightarrow ^{A-4}_{Z-2}\mathrm{Y} + ^{4}_{2}\alpha$.

   a) $^{230}_{90}Th$ [thorium, radium]

For thorium-230, the daughter element is $^{230-4}_{90-2}\mathrm{Y} = ^{226}_{88}\mathrm{Y}$.
On the periodic table, the element with $Z = 88$ is radium.
$^{230}_{90}\mathrm{Th} \rightarrow ^{226}_{88}\mathrm{Ra} + ^{4}_{2}\alpha$

   b) $^{238}_{92}U$ [uranium, thorium]

For uranium-238, the daughter element is $^{238-4}_{92-2}\mathrm{Y} = ^{234}_{90}\mathrm{Y}$.
On the periodic table, the element with $Z = 90$ is thorium.
$^{238}_{92}\mathrm{U} \rightarrow ^{234}_{90}\mathrm{Th} + ^{4}_{2}\alpha$

c) $^{214}_{84}Po$ [polonium, lead]

For polonium-214, the daughter element is $^{214-4}_{84-2}Y = ^{210}_{82}Y$.
On the periodic table, the element with $Z = 82$ is lead.
$^{214}_{84}Po \rightarrow ^{210}_{82}Pb + ^{4}_{2}\alpha$

3) Calculate the energy released during α-decay of these nuclei:

a) $^{230}_{90}Th$ [7.641×10^{-13} J]

$^{230}_{90}Th \rightarrow ^{226}_{88}Ra + ^{4}_{2}\alpha$

230.033134 u → 226.025410 u + 4.002603 u

230.033134 u → 230.028013

$\Delta m = 5.121 \times 10^{-3}\ u \left(\frac{1.66 \times 10^{-27}\ kg}{u}\right) = 8.50086 \times 10^{-30}\ kg$

$E = mc^2 = 8.50086 \times 10^{-30} (3.00 \times 10^8)^2$

$E = 7.651 \times 10^{-13}\ J$

b) $^{238}_{92}U$ [6.839×10^{-13} J]

$^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}\alpha$

238.050788 → 234.043601 + 4.002603

238.050788u --> 238.046204u

$\Delta m = 4.584 \times 10^{-3}u = 7.60944 \times 10^{-30}$ kg

$E = \Delta mc^2$

$E = 7.60944 \times 10^{-30}(3.00 \times 10^8)^2$

$E = 6.848 \times 10^{-13}$ J

c) $^{214}_{84}Po$ [1.255×10^{-12} J]

$^{214}_{84}Po \rightarrow ^{210}_{82}Pb + ^{4}_{2}\alpha$

213.995201u --> 209.984189u + 4.002603u

213.995201u --> 213.986792u

$\Delta m = 8.409 \times 10^{-3}$ u $= 1.395894 \times 10^{-29}$ kg

$E = \Delta mc^2$

$E = 1.395894 \times 10^{-29}(3.00 \times 10^8)^2$

$E = 1.256 \times 10^{-12}$ J

4) Find the elements produced by β^- decay of:

Use the pattern ${}^{A}_{Z}X \rightarrow {}_{Z+1}^{A}X + {}^{0}_{-1}\beta$. The atomic number must increase by one without changing the atomic mass number.

a) ${}^{228}_{88}Ra$ [${}^{228}_{89}Ac$]

$${}^{228}_{88}\text{Ra} \rightarrow {}^{228}_{89}\text{Ac}^{+} + {}^{0}_{-1}\beta$$

b) ${}^{212}_{82}Pb$ [${}^{212}_{83}Bi$]

$${}^{212}_{82}\text{Pb} \rightarrow {}^{212}_{83}\text{Bi}^{+} + {}^{0}_{-1}\beta$$

5) For thallium-202:

a) What isotope will β^+ decay of thallium-202 produce? [mercury-202]

During β^+ decay, the atomic number decreases by 1. When the atomic number of thallium decreases by 1, it becomes $Z - 1 = 81 - 1 = 80$, which is the atomicnumber for mercury.

b) Write the process for this decay. [${}^{202}_{81}Tl \rightarrow {}^{202}_{80}Hg + {}^{0}_{1}\beta + \nu$]

Use the general pattern ${}^{A}_{Z}X \rightarrow {}_{Z-1}^{A}Y + {}^{0}_{1}\beta + \nu$ for β^+ decay: ${}^{202}_{81}\text{Tl} \rightarrow {}^{202}_{80}\text{Hg} + {}^{0}_{1}\beta + \nu$

c) How much energy will be released by the decay of the thallium-202 nucleus if the mass of the thallium nucleus decreases by 0.001 463 u? [0.3400 MeV]

$\Delta m = 0.001463 \text{ u} - 2(5.485799\text{u} \times 10^{-4})$

$\Delta m = 3.658402 \text{ u} \times 10^{-4}$

E = 3.658402 u x 10-4 (931.5 MeV/u)

E=0.3408 MeV

6) Identify each type of decay in this series, and name the parent and daughter elements.

(a) ${}^{232}_{90}\text{Th} \rightarrow {}^{228}_{88}\text{Ra}^{*} + {}^{4}_{2}\alpha$ [alpha, thorium, radium]

(b) ${}^{22}_{11}\text{Na} \rightarrow {}^{22}_{10}\text{Ne} + {}^{0}_{1}\beta + \nu$ [beta, sodium, neon]

(c) ${}^{228}_{88}\text{Ra}^{*} \rightarrow {}^{228}_{88}\text{Ra} + \gamma$ [gamma]

(d) ${}^{228}_{88}\text{Ra} \rightarrow {}^{228}_{89}\text{Ac} + {}^{0}_{-1}\beta + \overline{\nu}$ [beta, radium, actinium]

(e) ${}^{228}_{89}\text{Ac} \rightarrow {}^{228}_{90}\text{Th} + {}^{0}_{-1}\beta + \overline{\nu}$ [beta, actinium, thorium]

(f) ${}^{228}_{90}\text{Th} \rightarrow {}^{224}_{88}\text{Ra} + {}^{4}_{2}\alpha$ [alpha, thorium, radium]

(g) ${}^{0}_{1}\text{p} \rightarrow {}^{0}_{0}\text{n} + {}^{0}_{1}\beta + \nu$ [beta, proton, neutron]